Constructing "calculus readiness": Struggling for legitimacy in a diversity-promoting undergraduate engineering program

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1. Introduction

How do newcomers to engineering, such as engineering students, become recognized members of the profession? Situated learning theory [1] proposed the notion of *legitimate peripheral participation* as central to a newcomer's trajectory toward membership in a community of practice. This approach left a number of issues underdeveloped, [2, 3, 4] incluing the issue of what are the processes by which legitimacy was conferred or denied. This is a critically important question in engineering education, given persistent and only partly successful efforts to increase representation in the field of members of historically underrepresented groups.

Our objective in this paper is to address these questions by considering the relationship between institutional category systems and the processes by which legitimacy is conferred upon newcomers. To do so, we draw on two key theoretical constructs. *Trajectories of membership* [1, 5] describe the adoption of and conferral of identities upon newcomers. *Trajectories of naturalization* [5, 6] describe the ways in which objects— that is, "stuff and things, tools, artifacts and techniques, and ideas, stories, and memories—objects that are treated as consequential by community members" [5 , p. 298]—enter into and become naturalized within a community of practice.

We show how students orient to a category of "calculus readiness"—itself tied to a longstanding identification of engineering with mathematics. This category entered into students' trajectories to produce a space in which the legitimacy of students in a diversity-promoting program was contested, both by the students themselves and by institutions. We highlight the ways in which students and staff in the diversity initiative struggled for legitimacy within this space, and we discuss the multiple trajectories of membership that resulted from this struggle. By providing insight into the contentious process by which legitimacy is conferred on newcomers to engineering, this paper takes a first step towards addressing the unjust underrepresentation of many communities in the engineering profession.

2. Theoretical Perspective

The theoretical perspective adopted in this paper is that of situated learning theory [1], also known as situativity theory [7, 8]. Situated learning theory, as understood here, is a general theory of learning that claims that *all* action, cognition, and learning are situated in social, cultural, and material contexts [9, 10]. The aim of the approach is to account for how persons are produced within particular social orders [1, 4, 11].

Early work within this perspective, perhaps most notably the highly influential work of Lave and Wenger [1], developed this view of learning as a trajectory of participation in a community of practice by focusing on how newcomers to a community move from "legitimate peripheral participation," in which they have access to authentic practices of a community but less than full responsibility for their performance, towards full participation in the practices of the community. This work served as an important inspiration for researchers who are critical of dominant, especially cognitivist, paradigms in formal educational settings, and who have attempted to design contexts for learning in schools, sometimes called "cognitive apprenticeships" [12], that take seriously the claims of situated learning. These approaches faulted traditional approaches to schooling for too often producing "inert knowledge" [13], that is, abstractions that learners are unable to apply in concrete situations. In contrast, these approaches aimed to produce "useable, robust knowledge" by situating learners in "authentic" contexts [12]. Rather than aiming for learning that results in supposedly decontextualized knowledge, cognitive apprenticeships attempted to provide students with access to legitimate peripheral participation in valued social practices, such as the practices of academic disciplines. This work has proceeded by explicitly modeling the "knowledgeable skills" of a discipline, and using these models to design "structures of participation" [7] for placement in classrooms and other learning contexts. Through participation in practices modeled upon those in particular target communities or disciplines, students are meant to serve as apprentices in the social practices associated with those communities, a process that is intended to result in "improved participation" in those practices and communities [7].

As Johri et al. [8] point out, situated learning theory has now developed to the point that it can be viewed not as a small critical movement in opposition to cognitivism but as a full-fledged approach to studying learning that stands alongside cognitivism. At the same time, Johri et al. point out, virtually since the onset of situative theories, there have been voices arising from within the situative approach that have challenged some of the ways in which that approach has developed and been used. Indeed, Jean Lave, perhaps the most influential thinker in the development of situated learning theory, has herself recently critiqued Lave and Wenger's *Situated Learning* [1] and some of the uses to which that work has been put. Lave [2] suggests that "[m]any who use the concept of 'communities of practice' now seem ignorant of the original intent (and its limitations), and simply assimilate it into conventional theory" [2, p. 283].

Lave & Wenger themselves did not focus on designing learning contexts, instead emphasizing the critical analysis of learning and educational practice as sites for the production, reproduction, and transformation of forms of social organization. These authors in fact explicitly distanced themselves from attempts to design learning contexts. They argued that legitimate peripheral participation is "not itself an educational form, much less a pedagogical strategy or teaching technique," and went on to question the value of "attributing a prescriptive value to the concept of legitimate peripheral participation and . . . proposing ways of 'implementing' or 'operationalizing' it for educational purposes." [1, pp. 40-41].

In this paper, we take up Lave's [2] assessment that in some ways, the uses of situated learning theory "assimilate it into conventional theory," and we claim that this assimilation threatens to rob the approach of some of its critical intent. It is important to note that we do not mean to imply that attempts to create "cognitive apprenticeships" [12] or "practice fields" [14] are not a useful and legitimate aspect of the situativity perspective. Rather, our aim is to show how different ways of understanding situated learning open up different analytic strategies in the study of engineering education.

In this more critical understanding of situated learning, mastery of new knowledgeable skills is not the only or primary consideration in understanding learning. Lave and Wenger [1] argued that "learning only partly— and often incidentally—implies becoming able to be involved in new activities, to perform new tasks and functions, to master new understandings" (p. 53). Particular knowledgeable skills take on significance and become consequential only as part of systems of relations within a social community, and learning "thus implies becoming a different person with respect to the possibilities enabled by these systems of relations" (p. 53). For example, Lave [15], describing the tailors' apprenticeships that she studied in Liberia, wrote,

> The apprentices were learning many complex "lessons" at once. To name a few: they were learning relations among the major social identities and divisions in Liberian society which they were in the business of dressing. They were learning to make a life, to make a living, to make clothes, to grow old enough, and mature enough to become master tailors, and to see the truth of the respect due to a master of their trade. (p. 151)

In this sense, learning involves identity formation, where identity involves becoming recognized, and recognizing oneself, as a member of a community. Learning is thus fundamentally a relational and not an individual phenomenon.

Bowker & Star [5] made a key conceptual contribution to understanding culturally, historically and institutionally situated participation by distinguishing between two different aspects of how trajectories of participation are organized: *trajectories of membership* and *trajectories of naturalization*. Trajectories of membership involve the adoption of and conferral of identities upon those within a community or social world. This dimension is a relation of people and membership. Trajectories of naturalization involve the way objects become taken-for-granted in a community, where objects are "stuff and things, tools, artifacts and techniques, and ideas, stories, and memories—objects that are treated as consequential by community members" (p. 298).

Most learning research on trajectories of participation involves an emphasis on trajectories of membership, without careful attention to how objects that have become naturalized through contingent historical processes enter into ascriptions or denial of membership. But Bowker & Star make clear that this naturalization of objects is crucial in understanding membership because it is the process through which norms and values become embodied in practices of everyday life. In this perspective, interactions among people are always mediated by objects, because it is through objects of various kinds that people become seen as a certain type of people. To draw on our work for an example, an engineering student who can't pass calculus, no matter how talented she is in other ways that might eventually be recognized as important in engineering practice, will not get to remain an "engineering student"—calculus ability, understood in terms of specific accountable knowledge displays [16], has become a deeply naturalized and taken-for-granted aspect of engineering and engineering education, and assessments and identifications of students who are on a trajectory toward becoming an engineer are made on the basis of this naturalized object.

The contribution that notions of objects and naturalization make to our understanding of trajectories of participation can be seen in Bowker and Star's view of communities of practice:

> The relationship of the newcomer to the community largely revolves around the nature of the relationship with the objects and not, counterintuitively, directly with the people. This sort of directness only exists hypothetically—there is always mediation by some sort of object. Acceptance or legitimacy derives from the familiarity of action mediated by member objects. (p. 299)

This perspective on membership and legitimacy foregrounds the role of action mediated by objects. Bowker and Star make clear that dynamics of membership and trajectories of naturalization can be analytically distinguished, but in life, the histories of objects and cultural practices that mediate our participation in given contexts are hard to disentangle. We suspect this is why these concepts have been challenging to access and leverage in social analysis by learning scientists and other researchers.

In our studies of engineering education, we find this dual focus on processes of membership and identification, and processes of classification and naturalization to be particularly powerful. Below, we illustrate how attention to both can help us understand how naturalized objects and classifications systems serve to produce trajectories that reproduce injustices.

3. Research Method

We conducted field-based ethnographic work centered on students, faculty, and staff involved in a diversity program in a prestigious U.S. college of engineering. The goal of our data collection was to capture student experiences and the ways in which those experiences were organized. We used a variety of fieldwork methods including ethnographic observations of routine activities, ethnographic interviews, and focus groups. Our data include fieldnotes, meeting minutes, and video and audio recordings. Our analysis involved concurrent engagement in data collection and data analysis, using Constant Comparative Analysis. We analyzed data from initial fieldwork early in the research process, leading to a preliminary "grounded theory," which led in turn to further fieldwork to refine the theory, and so on through multiple iterative cycles.

4. Research Context

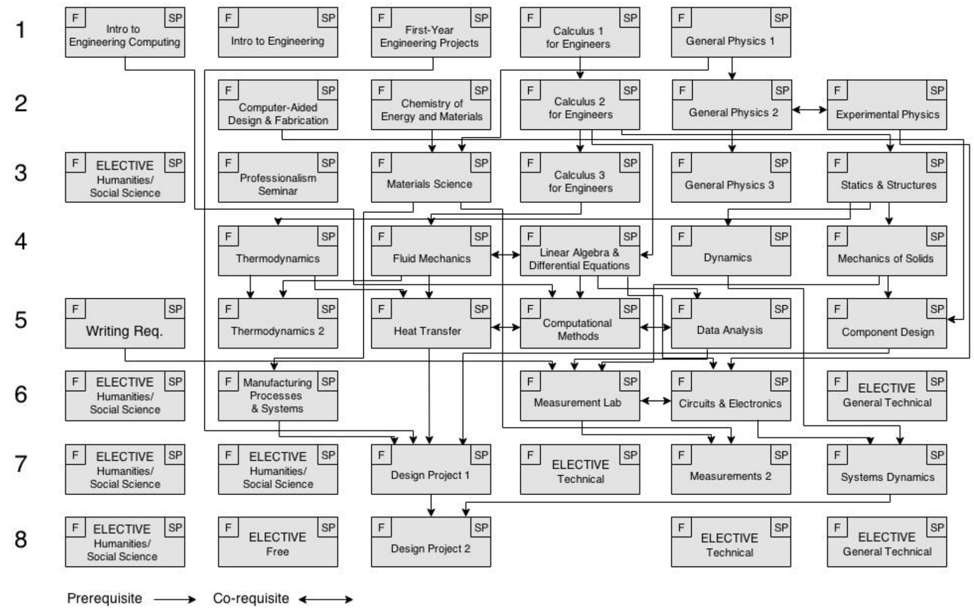
Our research focuses on the experiences of students in a diversity program in the engineering school at State U., a flagship state university in the Western United States. Like many universities, State U. uses a curriculum flowchart to communicate course sequences to students. Curriculum flowcharts, such as the one shown in Figure 1, are ubiquitous at State U., so much so that they are easily taken for granted, as are the course sequences they ascribe. But, as Seely [17, 18] shows, today's course sequence is the result of historical struggles, continuing into the present, over the identity of engineering and engineering education, such as those fought over the role of mathematics and project based learning in the curriculum. The outcomes of these struggles have become insinuated into the practices of institutions like State U., encoded or "naturalized," to use Bowker & Star's term, into the institutional infrastructure through such artifacts as curriculum flowcharts.

One way to see this naturalization is to examine the role of math courses on the one hand, and projects courses on the other. First, notice the centrality of math and science courses. This can be seen by examining the dependency trees for courses with pre-requisites. All of these dependency trees include math and science courses. Now, compare this with the two "projects courses" that are part of the first and fourth year. As shown, these courses are widely separated and generally disconnected from the rest of the curriculum. Within math and science courses, the course called "Calculus 1 for Engineers" stands out. This is arguably the most important course in the sequence, as it is part of every dependency tree, and it is the only course for which this is true. Furthermore, it is the first course in each of these dependency trees. In other words, the first step to accessing any course with a pre-requisite is passing Calculus 1.

The flowchart invites classification of students according to whether they have passed particular courses. For math courses, this classification is done via two connected practices: testing and grading. Depending on the grade a student receives, she is either granted or denied passage through the flowchart. Via the flowchart, the institution *legitimizes* certain students and *delegitimizes* others; students whose activities correspond with those inscribed in the flowchart are legitimized whereas students whose activities deviate from the flowchart are not. Because of the way calculus is naturalized in the flowchart, passing calculus is an activity that legitimizes a student.

As Nespor [19, 20] points out, curriculum flowcharts provide resources for students to locate and construct themselves in relation to the institution. The flowchart produces a standardized "path" onto which students locate themselves. For example, students talk about being "ahead" or "behind." This is a value-laden process; it is much better to be "ahead" than "behind," and being "behind" brings with it costs in terms of money, time, and status. More than any other course, students in our study indexed Calculus 1 as central to their path through the curriculum, and a key driver of whether they were "behind." Notice that these categorizations are based on certain assumptions (e.g., an assumption that mathematics is central to engineering) that were once, as Seely [17] argues, local, situated, and fought over, and are now naturalized.

Figure 1. A typical State U. Engineering Curriculum Flowchart



The Access program

The College of Engineering at State U is predominantly composed of white, male, middle- and upper-class students. *Access* is a program that seeks to broaden access to the college by admitting a cohort of approximately 30 "next-tier" students to the college each year. Students in the Access cohorts were initially denied admission to the College of Engineering, but were accepted via the Access program after a second round of admission screening. The Access program has explicit diversity goals, and is composed almost entirely of women, students of color, and first-generation college students. Although these students are admitted directly to the College of Engineering, they are enrolled in a "performance-enhancing year," in which they take courses designed to prepare them for courses in the regular engineering curriculum—that is, courses that are on the flowchart.

The Access program has now enrolled six cohorts of students. From the beginning, the program has faced opposition from some faculty in the school of engineering, who see the program as a sign that the school is "lowering standards." This opposition became especially salient for Jocelyn, the director of the Access program, in the program's third year when she realized that the preparatory math sequence was not in fact preparing students for calculus. In a focus group she explained, "when we saw our kids failing, were like, 'oh crap, we're about to lose this program.'" At State U., calculus doesn't just legitimize students, it legitimizes *programs*.

Calculus I at State U has a 30% failure rate, and, because it's so central in the flowchart, this leads to attrition in the engineering school. Still, it's largely untouchable. From Jocelyn's perspective, "changing calculus is like moving an elephant—a mountain." So rather than change calculus, the Access program changed the sequence of preparatory courses. They worked with the math department to create a new pre-calculus course, and they hand picked the instructor. Students in the fourth cohort had the option to take the new pre-calculus course. Below, we describe one such student. This student did not opt to take the pre-calculus course , opting instead to enroll in a year-long Calculus 1 course, which we note is also not represented on the flowchart.

5. Cases

Peter

Peter is a White, first generation college student, and is legally blind and partially deaf. In high school, he had been part of a school robotics team, and his science teachers had encouraged him to become an engineer. He recalls that he didn't really know what engineering was, but that he liked making and building stuff. Peter applied to several different engineering schools, with a preference for State U. because it was "better" than the other schools to which he had applied. Like all students in the Access program, he was initially rejected by the College of Engineering, but was later admitted into the Access Program.

Peter has struggled with gaining legitimacy in engineering through the naturalized route of displays of mathematical competence, a struggle that is mediated through the classification systems of the discipline and the practices that are organized around it. At the same time, he is engaged in considerably more "actual engineering" [21] than most students in the College of Engineering. He has invented and patented a device and started a business around it. This does not currently locate him on a trajectory to legitimacy within the College, for reasons that we will describe. The specific complexities of Peter's case are what make this a useful case to consider in a more complicated way of understanding how people become—or fail to become—engineers.

One commonsense way to tell Peter's story would be to say that he is "behind" in the flowchart. Indeed this is the institution's story about Peter, and even Peter's own story at times. In high school, Peter took "regular math," which did not include calculus. Most students in the School of Engineering did take calculus in high school, and either moved right onto the flowchart or even jumped "ahead" by two or more semesters. But Peter, like many Access Program students, didn't even start *on* the flowchart. Based on his score on a placement test at the beginning of his first year, Peter took a two-semester version of Calculus 1 for engineers, a course that is not even represented on the chart. Each of these courses took Peter two semesters to pass, which meant that it took him four semesters to finish Calculus 1—four times longer than the time allotted in the flowchart.

In the perspective that we're developing here, though, this commonsense story does not adequately capture Peter's trajectory. We need to look more deeply at Peter's experiences, and interrogate the ways that classification practices have framed and mediated these experiences. We see Peter's story as a story of a biographical trajectory "broken, twisted, and torqued" [5, p. 26] by infrastructure, a story of a trajectory of membership mangled by mathematics, which for Peter is an object of membership that refuses to be naturalized.

Recall first that Peter is legally blind. This classification in fact pulled Peter into the engineering school via the Access program. But the disability it represents pushes him to the borderlands of the flowchart when such taken-for-granted practices as presenting information visually on a board in front of the classroom interact with the impersonal nature of the flowchart. He explained to us in an interview:

> This semester, one of the reasons I'm doing bad is because everything is on the board, everything is written … It doesn't really seem like a problem to many people have, I guess, but, you know, when everything is written on the board, and they expect you to learn everything from the board, and you can't actually see the board, then it's huge. I've always been blind, but I made it through high school because I could talk to my teachers after that. But, you know, in college, now it's like, I have a class before and after, and I can't stay to talk to them.

It took Peter over a year to obtain an accommodation for his blindness, and he explains that part of the reason for this was that he lacked the money needed to pay for an eye screening. He says about the money needed to pay for the screening, "I guess it's not a big deal for a lot of people here, but for me it is. So that took a long time."

The flowchart simply cannot account for this. It groups large numbers of students (and their instructors) into courses in a standardized pathway, captured by boxes and arrows. Institutional practices of testing and grading squeeze students into—and push them through—this pathway. But an individual's trajectory becomes disrupted when it fails to accommodate to the naturalized trajectory of success in mathematics courses. This is where we find Peter. Calculus 1, a single-semester class on the flowchart, took him four semesters. Peter has been at State U. for three years according to calendar time (accumulating student debt during this time), but according to "flowchart time" he is still in his first year. Denied progress along the engineering flowchart, Peter finds himself taking classes in the College of Arts and Sciences. Taking these classes does more than add to the amount of time and money Peter has given State University; it also distances him from peers in the College of Engineering while simultaneously pushing him outside the boundaries of the trajectory that the flowchart normalizes and legitimizes.

Even inside the boxes of the flowchart, grading practices produce an unpredictable outcome for students. Because individual test and homework scores are not translated into grades until the end of the semester, students spend the entire semester accumulating scores without knowing whether these scores will result in passing or failing [22]. Depending on the semester, the course, and the mix of students in the course, a raw score of 78 could be a passing or a failing grade. For Peter this uncertainty has been especially pronounced. For each of his first four semesters, he was within two points of a passing grade. Twice he found himself on the passing side of the boundary. Twice he was on the failing side. For two full years, Peter lived with uncertainty about his status as an engineering student. Even halfway through his fifth semester, Peter was still uncertain whether he would pass Calculus 2. Peter is existing perpetually on a border between passing and failing, in doubt about an outcome that is highly consequential in his struggle for legitimacy.

There's little question that Peter and others are moving along trajectories that cause them discomfort, uncertainty, even suffering. Still, we see some reasons to be optimistic, about Peter's case and others. Despite his uncertain position, and even in part *because of* that position, Peter has engaged in authentic engineering, albeit unrecognized and not legitimized by the institution. Driven by worries that he will "get kicked out of the engineering school," Peter designed and patented a "high-end upgrade for 3-D printers," which he is currently selling online. This involved not only the design and production of the device itself, but also the assembly of heterogeneous elements into a viable business, including business plans, financial backers, patent lawyers and governmental infrastructure. We don't yet know whether Peter will eventually receive an engineering degree; we do know that he is actively seeking other forms of legitimacy that might not require one.

<u>Mary</u>

Mary is a white female student. Like Peter, Mary's experience in the Access program has been shaped by mathematics. She came into the program having taken calculus in high school, and expected that she would take calculus during her first semester. She never had the option, because, partly in response to the experiences of students like Peter, Jocelyn decided to enroll all students in Mary's Access cohort in Pre-calculus—a course which, unlike the two-semester calculus course that Peter started in, includes no calculus content. Instead, the goal of Pre-calculus is to help students become "calculus ready." After students pass Pre-calculus, they can enroll in either the one-semester or the two-semester version of Calculus 1. Hence, Pre-calculus comes "before" two-semester calculus in the course sequence.

While Jocelyn made the decision to enroll Mary and the rest of her cohort in Pre-calculus in order to enhance the legitimacy of Access students and the Access program, it also ensured that Mary would be "behind" on the flowchart. Mary explained:

> Almost all of the classes here for engineering are based off of calc, so if you're not caught up in calc you're gonna be behind in all of your other classes as well. And there's like no getting around it. So that means I'm definitely way behind other people in the engineering school.

One the one hand, such a position is expected for Access students. It's a natural outcome of the "performance enhancing year" that is at the heart of the program. From this perspective, Mary, who is taking Calculus I in the Fall semester of her second year at State U, isn't behind at all. She's exactly where the Access Program expects her to be. However, such a perspective fails to account for the lived experience of students like Mary, who is now taking what she calls "freshman classes" during her sophomore year. During an interview, her voice cracked as she described what this is like:

> [It's] kind of embarrassing almost, cause you feel like you can be smarter than this, and like moving on, but you're not. Yeah. I don't know. I, it's just, I don't know... I don't know (softly). I can't- I don't know how else to describe it.

Being "behind" is not a neutral category for Mary. It causes her to question her legitimacy as an engineering student, and negatively affects her sense of self.

This is not the only way that mathematics affects Mary's sense of self. She describes herself as someone who tries to "think things through," and "show all the steps." For her, this is what learning is. This is how to make learning "stick." However, at State U., Mary experiences mathematics as an exercise in answer-getting, and measures herself against her classmates via the speed at which those answers are obtained. In the segment below, she talks about doing slow, careful work in mathematics.

> Well, it's not good if you want to actually get stuff done. [Last semester] I would just run out of time to do stuff, because I spent so much time like, going through. And then my roommate is just like, 'oh, okay,' two calculations in the head, click, right answer. And so I have to write it out and everything, and she takes like literally half the time to do anything that I did and she would still do better than I did. And it's not a good thing for exams because that's kind of like, you've got to know it, you've got to write it out really fast. And you've got to know all the stuff, you can't just like stop to think for too long, otherwise you run out of time.

Running out of time turned out to be consequential for Mary. At the end of her first semester, based on her pre-calculus grade, she was categorized as "not calculus ready" and therefore had to repeat pre-calculus the following semester. Like Peter, Mary was positioned as illegitimate by mathematics. In large part, this was due to the way that mathematics was construed in the engineering school at State U. Because exams and other consequential knowledge displays were framed as answer-getting exercises that privilege speed over thoughtfulness, her pensive style went unrecognized by the institution.

As we write this, Mary is in the fall semester of her sophomore year. Last year, she was deemed to be calculus ready after her second semester of pre-calculus. Looking back, she describes pre-calculus as "very important" for calculus. In large part, this is because exam problems *made* pre-calculus important:

> [Pre-calculus] was very important. The first test was like over all things pre-calc basically. With a couple of calc things. […] They had a question on absolute value. And you learned like a lot about absolute value and translations and stuff [in pre-calc]. And you needed that information to solve a certain problem on the calc exam.

Under these circumstances, pre-calculus helped position Mary to perform on the consequential knowledge displays [16] that lead to legitimacy in calculus.

In addition, Mary's thoughtful style came to be recognized by the Access program. She was selected prior to her second year at the university to be a Learning Assistant (LA) for the pre-calculus course. LAs are undergraduates who help to facilitate small-group interaction in large-enrollment courses. As an LA, Mary is positioned as an expert in mathematics. Students look to her for help, and helping students is affirming for Mary:

> You feel like, kinda, proud of yourself and like, um, really happy that you got to help someone and like, make their life a little easier. Um, it's just, yeah, a really good feeling.

In addition to helping students, she works with and socializes with pre-calculus instructors, she helps to grade exams, and last semester she conducted an independent education research project that she presented at a poster session on campus.

In Mary, we see how mathematics becomes intertwined with legitimacy. In some ways, mathematics has pushed and continues to push Mary into the margins of the engineering school. This began with the Access program's decision to enroll Mary in pre-calculus—a decision that ensured that Mary would always be behind on the flowchart, but which, in retrospect, helped Mary gain legitimacy in calculus. It continues with the ongoing damage that timed tests inflict on Mary's sense of self. At the same time, mathematics has pulled Mary into a position of some power and authority within the engineering school, allowing her to build relationships and participate in practices that affirm her legitimacy.

6. Conclusion

As Peter and Mary stories make clear, "calculus readiness" is much more than neutral diagnosis of a cognitive state. Rather, it is a human-produced classification that is contingent on both history—including the struggles over the place of math and science in engineering—and contemporary institutional practices—including testing and grading, and presenting information visually on a board in class. Because calculus readiness legitimizes students and programs, it is value-laden, and therefore has consequences beyond course registration. It interacts with other institutional objects, including the flowchart, to "twist and torque" [5] trajectories: not only students' educational trajectories but also their biographical trajectories, and even the institutional trajectory of the Access program.

Peter's and Mary's stories are just two of many we could have told. Students in the Access Program experience engineering education in different ways, shaped differently depending on how their personal trajectories intersect with the naturalized classification systems of the College of Engineering. Some students in the program find themselves caught between high school and college, in their "5th year of high school" or "3rd semester of senior year," when their expectations of what college should be—largely based on the flowchart—is in tension with the year of "extra preparation" required by the Access Program. A different student is caught between financial responsibilities to her working class immigrant family and Access Program expectations that work at paid jobs can be limited to under ten hours per week—an expectation based upon the workload required to stay on the flowchart, and an expectation that would cause little difficulty for the largely upper middle class students that make up the majority of the School of Engineering. Yet another finds himself overwhelmed by what he calls "culture sickness" and depression, caught between the unfamiliar white middle class culture of the College of Engineering and State U. more generally and his own home community of Mexican immigrants in a city a couple of hours away—too great a distance to easily travel and still keep up with the work required in order not to fall too far "behind" on the flowchart.

Students in the Access Program are routinely engaged in struggles for legitimacy, struggles to be recognized as valued and legitimate participants in the College of Engineering. That they are engaged in these struggles should not be surprising; they were initially rejected by the College of Engineering—in most cases because they had not performed sufficiently well in displays of knowledge related to the mathematical core of engineering—only to gain entry at least partly on the basis of the very aspects of their personal trajectories that would later come to marginalize them. Their struggles are being actively produced by the varied trajectories of membership and naturalization along which they and the College of Engineering are traveling.

Given these struggles, what can be done to minimize them? In this paper, we can only offer tentative suggestions. First and foremost, we have shown that struggles for legitimacy are often produced by institutional practices. Therefore, a first step is for institutions to interrogate these practices with an eye towards changing them to be more inclusive. In the case of "calculus readiness," an institution might ask about the central location of math and science in the engineering flowchart, and interrogate whether this is the most appropriate way of organizing the curriculum. We watch with interest a growing chorus of researchers and practitioners [23-25] who suggest that making *design* the central feature of the curriculum (rather than math and science) might be more appropriate to the work of engineering, and quite possibly more inclusive. We are exploring this in our current work.

Institutions might also interrogate the ways that math and science courses are taught. Often, undergraduate students experience math courses as Mary did, that is, as exercises in answer-getting.[26] Such courses are teacher-centered, and they privilege narrow mathematical competencies (such as memorization and calculation speed) and knowledge displays (such as testing) that have little to do with engineering practice. [16] This, in turn, legitimizes a small group of students while marginalizing others who have a wealth of other assets that are not leveraged in math class.[27-30] Again, the marginalization is a function of how courses are *organized*, and should not be seen as deficits in individual students' cognitive states. More inclusive mathematics courses are student-centered [31, 32] and they position students as epistemic and historical agents. Epistemic agency involves giving students the authority to make and share meaning in the classroom.[27, 33-35] Historical agency involves positioning students as historical actors who can use mathematical understandings to read the world from a critical perspective and to author new roles for themselves in new, more socially just visions of the world.[36, 37] As these courses relocate agency, they also reposition student's histories, families, communities, and cultural practices as sources of assets rather than deficits.[36, 38] What this means is that students' cultural backgrounds are brought into, rather than excluded from, the classroom. The resulting heterogeneity is leveraged as a resource for all students, leading to opportunities for understandings that include, but go beyond, those which are privileged in traditional classrooms.

At the same time, for those of us interested in understanding and supporting diverse learning trajectories, and the dynamics of membership and histories of naturalization that mediate them, it is important to pay attention to agency and resistance in the face of naturalized categories that push some people to the margins. These efforts highlight the way that marginality can become a space of possibility [39], and we view resistance born of "failure, loss, destruction" [40] to be a worthy focus of research in engineering education.

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